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EFFECT OF PHOTOPERIOD ON RICE VARIETIES GROWN IN THE FIELD[1]

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INTRODUCTION

Hundreds of varieties of rice (*Oryza sativa* L.) have been introduced into the United States from the principal rice-producing countries of the world for possible use in rice improvement. When varieties introduced from the Tropics are grown in the Southern States, they often fail to head or else head so late that they do not set seed or mature before the plants are killed by cold. This behavior in the United States apparently is due to the longer days, which delay heading, and to the cooler weather, which retards maturity, as compared with conditions in the Tropics.

Many tropical varieties, when grown under long natural daylight periods in temperate regions, make a rather vigorous vegetative growth and have a tendency to continue growth until the short days of late autumn. They may then head slowly and unevenly, set a few seed on comparatively long panicles, but fail to mature normally. On the other hand, some late-maturing varieties from temperate regions, when grown in the Tropics under relatively short-day conditions, produce rather small plants with few tillers, bearing short panicles that set seed and mature much earlier than in temperate climates.

Fortunately, certain varieties from the Tropics head early enough to mature seed in the South, and these or selections from them have proved to be well adapted for growing there. Rice breeders are fortunate in that among the rice varieties grown in various parts of the world there may be found marked differences in physiological response to light and temperature conditions.

The known photoperiodic response of rice varieties can be used to advantage by rice breeders in controlling the time of heading of varieties to be used in hybridization. Also, information as to varietal reaction to early and late seeding can be obtained by tests of photoperiodic response. The present paper reports the effect on time of heading and plant growth of different day lengths obtained by covering field-grown plants to exclude light for various periods.

REVIEW OF LITERATURE

The effect of the relative length of day and night upon the time of flowering of plants, reported by Garner and Allard (*4, 5, 6*),[2] has been studied by numerous investigators working with rice. In pot experiments, in which a few plants per treatment were used, Eguchi (*2*),

[1] Received for publication March 27, 1942. Cooperative investigations of the Division of Cereal Crops and Diseases, Bureau of Plant Industry and the Texas Agricultural Experiment Station.

[2] Italic numbers in parentheses refer to Literature Cited, p. 340.

Fuke (*3*), Kondo et al. (*9*, *10*), Miyashiro (*11*), Noguchi (*12*, *13*), Tabata et al. (*15*), and Yoshii (*16*) all report a reduction in the number of days required for rice to reach the heading stage when the length of day was shortened. In date-of-seeding experiments in pots and under field conditions, Adair (*1*), Jenkins (*7*), and Scripchinsky (*14*) reported a reduction in the time required for rice to mature as date of seeding was delayed.

Tabata et al. (*15*) limited Japanese rice varieties to 8 hours of sunlight per day as early as 54 days after seeding. The earliest treatments reduced the time from seeding to heading as much as 22 days, whereas the treatments begun after the plants were well advanced had no effect on time of heading. The short-day treatments reduced the yield of grain.

Miyashiro (*11*) found that a 10-hour daylight period, beginning 84 to 86 days after seeding, hastened heading by about 1 week. He also reported that light interception during the morning delayed heading 8 to 9 days, whereas afternoon light interception had no effect on time of heading.

Yoshii (*16*) used a 9-hour light period, beginning at an early stage of plant development, and reduced the time required from seeding to heading of late varieties by about 2 weeks. He also reported that daily light periods of 5 and 9 hours, especially with late-maturing varieties, increased the number of tillers per plant and slightly reduced the length of panicles, yield of grain, and plant height.

Fuke (*3*) concluded that, as a rule, short-day treatments are most effective when used on plants that have seven to nine leaves and are beginning to tiller freely. Treatments starting 30 days prior to natural heading are slightly less effective, and treatments beginning before the plants have seven to nine leaves, or 16 days prior to natural heading, are relatively ineffective.

Kondo et al. (*10*) found that short-day treatments increased the number of tillers and had no effect on length of panicles but caused a reduction in grain yield and plant height. They also reported that rice grown under 8 hours of light per day, divided into two or three periods in which the over-all time from beginning to end of photoperiod was 12 hours, headed at essentially the same time as when grown under a continuous 8-hour light period. When grown with 12 hours of light, divided into two periods in which the over-all time from beginning to end of photoperiod was 16 hours, the plants reacted as to a long day and did not head. When grown with 12 hours of continuous light, the plants reacted as to a short day, and heading was accelerated. They also found that the time of heading of an extremely early variety from Hokkaido, Japan, grown under a short-day treatment, was unaffected, whereas the time of heading of an extremely late Formosan variety was greatly accelerated by the short day.

In other studies, Kondo et al. (*9*) limited the daily light periods from transplanting to heading to 8 or 12 hours. The treatments reduced the time to heading by as much as 1 to 2 months. They also reported two periods of heading for seedlings limited to 8 or 12 hours of daylight during the entire seedbed period followed by normal daylight. The first period was much earlier and the second later than normal.

Eguchi (*2*) placed early- and late-maturing rice varieties in different groups based on their reaction to short-day treatments. In late-

maturing varieties, the short-day treatment accelerated the differentiation of flower buds but, when continued, had no effect upon subsequent development of the differentiated buds. In the case of early-maturing varieties, both time of differentiation and further development of flower buds were found to be independent of day length.

Jenkins (*7*), in commenting on date-of-seeding experiments with rice, stated that—

> Some varieties tend to have a comparatively fixed growing period, while in others it appears that heading will not take place until a certain time in the fall after which their growing periods shorten materially.

Date-of-seeding experiments reported by Adair (*1*) show that the rice varieties referred to as "sensitive" decreased markedly in plant height and in time required to reach the heading stage as the seeding was delayed. Varieties referred to as "indifferent" in most cases showed no consistent differences in plant height and smaller and less consistent differences in time required to reach the heading stage as the date of seeding was delayed.

MATERIAL AND METHODS

In 1936, 10 varieties of rice, growing in the field at substation No. 4 of the Texas Agricultural Experiment Station at Beaumont, Tex., were subjected to controlled photoperiods during different stages of growth. Jones (*8*) has described 6 of the varieties grown in this study. Of the remaining 4, Kameji is a midseason, short-grain Japanese variety and C. I.[3] 6993 is a very early, short-grain Japanese variety. C. I. 81C and C. I. 4700, medium-grain varieties that tiller profusely, were introduced from the Philippine Islands. The first-named variety matures early, while the latter matures very late.

A single row 203 feet long of each variety was sown on April 13. The rows were spaced 8 inches apart and the seeds were spaced 4 inches apart within the rows. The first seedlings emerged on April 29, and all seedlings had emerged by May 6. The area was divided into 58 plots, and each plot included a 3½-foot-row section of each variety. The treated plots were distributed in a systematic fashion along with 4 untreated or normal-day plots. The treated plots were duplicated.

The length of day was controlled by covering the plants for definite periods with frames covered with mumshade cloth.[4] These frames were 3½ feet wide, 8 feet long, and 2½ feet high. Medium-weight unbleached muslin was placed outside the mumshade cloth to reflect heat and thus assist in maintaining a nearly normal temperature under the cover.

The plants were covered daily for 10-day periods beginning June 1, 11, and 21, and July 1, that is, 49, 59, 69, and 79 days after seeding; for 20-day periods beginning June 1, 11, and 21; and for 30-day periods beginning June 1 and 11. On June 1 the plants were in the fourth-leaf stage and, with but few exceptions, had not started to tiller. Three length-of-day treatments, on adjacent plots, were obtained by covering the plants for the following periods: (1) From 6 p. m. to 8 a. m.; (2) from 8 a. m. to 1 p. m.; and (3) from 1 to 6 p. m.

The length and distribution of light and dark periods for the treatments and the natural days are shown in figure 1. Covering periods

[3] C. I. refers to accession number of the Division of Cereal Crops and Diseases.
[4] A black cloth for preventing light infiltration.

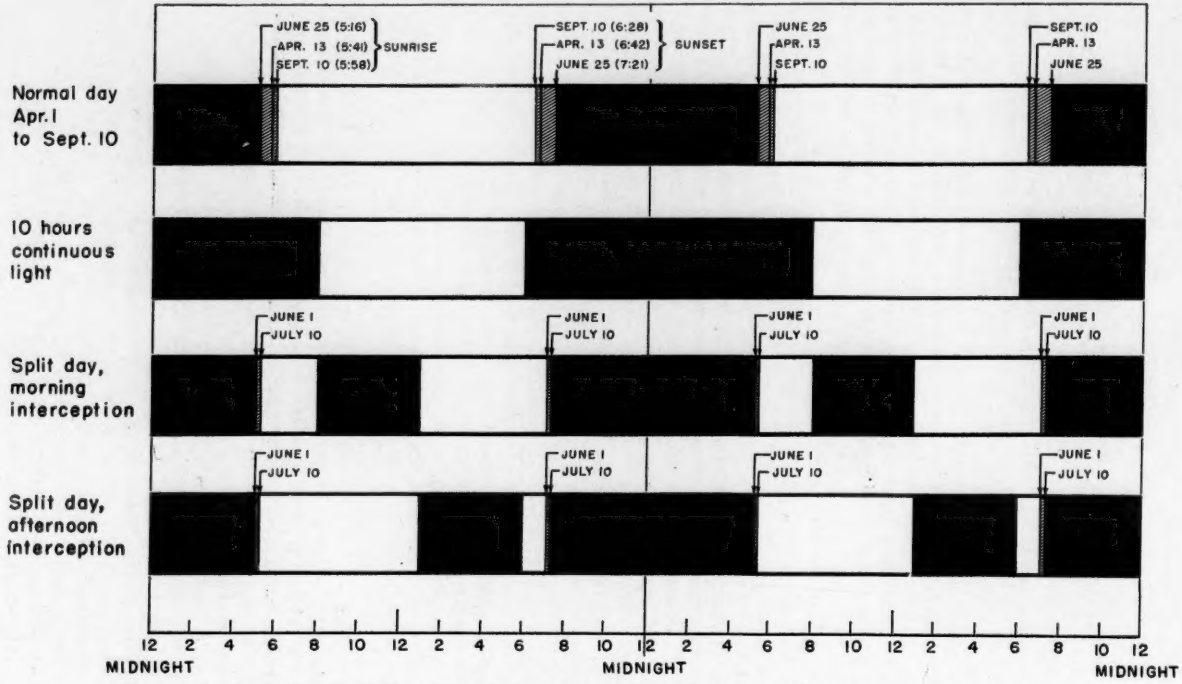

FIGURE 1.—Length and distribution of various light periods studied and length of the normal day on April 13, June 25, and September 10.

2 and 3 are referred to as the split-day treatment, because the plants received light from daybreak until covered and from the end of the covering period until darkness.

The number of hours between sunrise and sunset during the growing season ranged from 13 hours 1 minute, on April 13, to 14 hours 5 minutes, on June 25. By September 10 the normal day had been reduced to 12 hours 30 minutes. On June 1, when the covering treatments were started, and on July 10, when they ended, there was 13 hours 57 minutes between sunrise and sunset.

Data were obtained on an average of 14.6 plants of each variety for each covering period and 29.9 plants of each variety for the control (plants of normal-daylight period), making a grand total of 4,227 plants in all treatments. The various characters studied for each plant were: (1) Date of first panicle emergence from the boot; (2) number of tillers and panicles; (3) length of panicle on tallest tiller and height of tallest tiller; (4) average grain and straw weights. The average grain and straw weights are based on the total weights of grain and straw per row divided by the number of plants. Student's test for unique samples was used to determine whether the differences between plots covered from 8 a. m. to 1 p. m. and those covered from 1 to 6 p. m. were significant.

EXPERIMENTAL RESULTS

TIME OF HEADING

The effect on the number of days required from seeding to first panicle emergence of 10-hour photoperiods for 10, 20, and 30 days, beginning at different stages of growth, is shown in table 1. The varieties were placed in two groups, based on their reaction to the short-day treatments. In group 1, the "sensitive" varieties, a marked reduction in the number of days required from seeding to heading

TABLE 1.—*Effect on time of panicle emergence in 10 rice varieties of 10-hour photoperiods for 10, 20, and 30 days at different stages of growth*

Group and variety	Average plants per treatment	Average period to panicle emergence of control	Average period from seeding to first panicle emergence when covered daily for—								
			10 days beginning—				20 days beginning—			30 days beginning—	
			June 1	June 11	June 21	July 1	June 1	June 11	June 21	June 1	June 11
Sensitive varieties:	*Number*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
C. I. 81C	13.9	107.1	88.3	90.6	97.3	103.4	80.3	86.6	95.3	80.6	87.6
Caloro	12.9	114.2	86.6	91.2	98.2	107.4	83.1	88.0	96.5	80.7	88.0
Kameji	15.1	121.2	81.8	89.0	96.8	108.9	78.0	85.9	94.4	78.4	85.1
Improved Blue Rose	17.2	131.0	90.7	92.4	101.0	112.4	80.5	87.7	97.1	82.4	87.1
C. I. 4700	17.3	146.0	89.9	95.4	106.7	119.2	79.6	87.5	97.3	77.3	87.3
Average	15.3	123.9	87.5	91.7	100.0	110.3	80.3	87.1	96.1	79.9	87.0
Less sensitive varieties:											
C. I. 6993	5.6	85.5	78.8	83.0	85.8	86.4	77.2	81.4	86.2	80.0	84.0
Shoemed	15.4	115.7	113.8	103.8	103.0	108.7	96.4	94.3	100.0	93.5	93.2
Nira	16.0	124.6	126.6	124.4	118.2	118.1	125.3	114.8	110.8	117.7	110.6
Fortuna	15.9	124.8	125.2	125.0	119.5	117.4	125.4	117.3	111.7	123.5	114.3
Rexoro	15.0	145.8	147.6	145.3	129.8	125.6	147.6	120.5	112.5	138.9	109.5
Average	13.6	119.3	118.4	116.3	111.3	111.2	114.4	105.7	104.2	110.7	102.3

occurred for the earliest 10-, 20-, and 30-day covering periods, followed by a more gradual and less marked reduction as the date of covering was delayed. While there was a progressive increase in the number of days required to head for the successively later covering periods, all varieties treated headed earlier than the controls. The smallest reduction was 3.7 days for C. I. 81C, covered daily for 10 days beginning July 1, and the largest reduction was 68.7 days for C. I. 4700, covered 30 days starting June 1. The 10-, 20-, and 30-day covering periods had the same general effect on date of heading, but the longer covering periods showed slightly more effect.

All sensitive varieties, except a few plants and C. I. 81C, when covered for 10 days starting June 1, headed during two periods. The variety C. I. 4700 also reacted in this manner to a limited extent for the 10-day covering period beginning June 11. The short covering periods, at this stage of seedling development, caused the tillers on plants of these varieties to head early, whereas the tillers produced during and after the covering period were not affected by the short-day treatment and headed at essentially the same time as the control plants. Kondo et al. (*10*) also reported two periods of heading; the first was much earlier and the second later than normal.

The tabular data reported in this part of the paper on the time of heading, number of panicles, length of panicles, plant height, and the weight of grain and straw for the sensitive varieties, except C. I. 81C, for these covering periods (June 1 and June 11 for 10 days), are based on information recorded for the tillers that headed early. No information on the plant characters studied was recorded for the tillers that headed late for these particular varieties and treatments. However, it was observed that the late tillers were about normal in height and produced panicles that appeared to be of essentially the same length as those of plants of the normal-day length.

In group 2, the less sensitive varieties, the earliest covering periods for 10, 20, and 30 days showed in general a slight reduction in the number of days required from seeding to heading, followed by a gradual but more marked reduction as the date of covering was delayed. The variety C. I. 6993 did not behave in this manner but showed a maximum reduction in the time required to head for the earliest covering periods. This very early variety was placed in the less sensitive group because its response to the short-day treatments was not very marked. The other exception to the usual reaction of the less sensitive varieties was Shoemed when covered 10 and 20 days beginning July 1 and June 21 respectively. The reactions of the less sensitive varieties ranged from an increase of 2 days for Nira when covered 10 days beginning June 1, to a reduction of 36.3 days for Rexoro when covered 30 days beginning June 11.

The average effect of the short-day treatments on the number of days to heading, number of tillers and panicles, length of panicles, plant height, and the grain and straw weights per plant are shown in figure 2.

NUMBER OF TILLERS

The average number of tillers and panicles for the various covering periods is shown in table 2. The 10-day covering period beginning June 1 resulted in a marked increase in the number of tillers for the sensitive varieties Caloro, Kameji, Improved Blue Rose, and C. I.

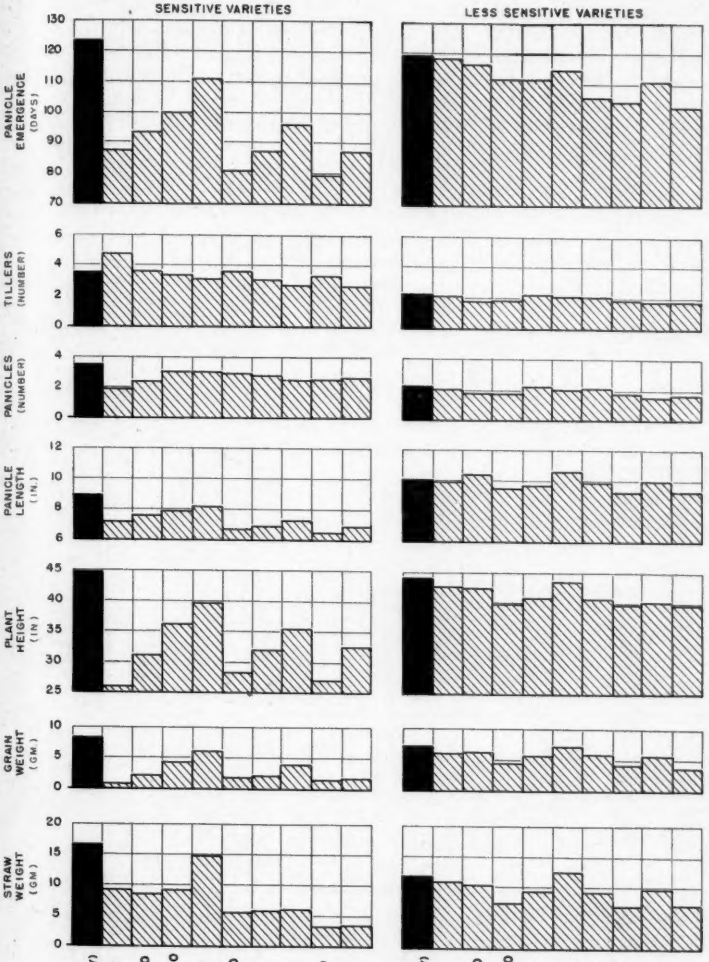

FIGURE 2.—Average effect of the short-day treatments on the number of days to heading, number of tillers and panicles, length of panicles, plant height, and grain and straw weights per plant.

4700, which headed during two periods, but not for C. I. 81C. The other short-day treatments, for both the sensitive and the less sensitive varieties, resulted in only slight increases or decreases in the number of tillers for the earliest covering periods, while for the later covering periods they brought about a gradual reduction in number. The greatest reduction was observed in plants covered 30 days (fig. 2). There was more variation in the number of tillers for the sensitive than for the less sensitive varieties.

TABLE 2.—*Effect on number of tillers and panicles per plant in 10 rice varieties of a 10-hour photoperiod for 10, 20, and 30 days at different stages of growth*

TILLERS

Group and variety	Average plants per treatment	Average tillers and panicles of control	Average tillers and panicles per plant when covered daily for—								
			10 days beginning—				20 days beginning—			30 days beginning—	
			June 1	June 11	June 21	July 1	June 1	June 11	June 21	June 1	June 11
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Sensitive varieties:											
C. I. 81C	12.8	4.61	4.50	3.25	3.87	2.35	3.85	3.62	2.77	3.58	2.83
Caloro	12.4	2.85	3.60	2.81	2.92	2.86	3.57	2.14	2.27	2.92	1.50
Kameji	12.3	2.78	4.00	2.75	2.26	2.67	3.18	2.29	2.25	2.83	2.83
Improved Blue Rose	13.2	3.17	4.00	2.84	2.64	2.69	3.38	3.36	2.59	3.33	2.00
C. I. 4700	16.0	4.50	7.85	6.47	5.05	5.00	4.14	3.76	3.50	4.11	4.18
Average	13.3	3.58	4.79	3.62	3.35	3.11	3.62	3.03	2.68	3.35	2.67
Less sensitive varieties:											
C. I. 6993	5.6	2.55	2.67	2.17	2.17	2.60	2.40	2.43	2.20	2.20	1.80
Shoemed	14.9	2.97	2.38	2.00	1.79	2.80	2.92	2.67	2.44	1.93	1.90
Nira	16.0	1.97	1.82	1.55	1.94	2.06	2.00	1.72	1.52	1.56	1.74
Fortuna	15.9	1.91	1.59	1.88	1.76	2.21	1.82	1.93	2.08	1.65	1.81
Rexoro	15.0	1.90	2.07	1.75	1.80	1.67	1.82	2.00	1.53	1.92	2.00
Average	13.5	2.26	2.11	1.87	1.89	2.27	2.19	2.15	1.95	1.85	1.85

PANICLES

Sensitive varieties:											
C. I. 81C	12.8	4.43	3.57	2.75	3.80	2.35	3.85	3.62	2.69	3.17	2.83
Caloro	12.4	2.73	2.20	2.25	2.85	2.79	3.14	2.00	2.27	2.83	1.50
Kameji	12.3	2.78	1.62	1.88	2.21	2.60	2.91	2.00	2.17	2.17	2.83
Improved Blue Rose	13.2	3.11	1.08	2.05	2.41	2.63	1.88	3.00	2.29	1.67	2.00
C. I. 4700	16.0	4.50	1.08	3.18	3.95	4.76	3.07	3.47	3.17	2.94	4.18
Average	13.3	3.51	1.91	2.42	3.04	3.03	2.97	2.82	2.52	2.56	2.67
Less sensitive varieties:											
C. I. 6993	5.6	2.55	2.67	2.17	2.17	2.60	2.40	2.43	2.20	1.80	1.60
Shoemed	14.9	2.84	2.38	2.00	1.74	2.67	2.17	2.61	2.13	1.36	1.90
Nira	16.0	1.97	1.65	1.55	1.88	2.00	2.00	1.72	1.52	1.38	1.74
Fortuna	15.9	1.91	1.47	1.88	1.59	2.14	1.76	1.93	2.08	1.65	1.63
Rexoro	15.0	1.90	2.07	1.75	1.67	1.67	1.71	1.92	1.53	1.75	1.92
Average	13.5	2.23	2.05	1.87	1.81	2.22	2.01	2.12	1.89	1.59	1.76

NUMBER OF PANICLES

On the whole, short-day treatments reduced the average number of panicles per plant for both the sensitive and less sensitive varieties (table 2). Neither group of varieties showed consistent increases or decreases in the number of panicles for the different covering periods, except for the sensitive varieties that headed during two periods as a

result of early covering (fig. 2). These varieties for the 10-day covering period beginning June 1, and June 11 for C. I. 4700, if both early and late tillers produced panicles, would probably show an increased number as compared with the control plants.

LENGTH OF PANICLE

The average panicle length for the various covering periods is shown in table 3. The average panicle length of the sensitive varieties was greatly reduced when the plants were covered 10, 20, or 30 days starting June 1; later covering periods showed less reduction. The less sensitive varieties showed little variation in panicle length for the different covering periods. However, the panicles in the later covering periods were slightly shorter than those of the controls, while in the early covering periods they showed no reduction (fig. 2).

TABLE 3.—*Effect on panicle length and plant height in 10 rice varieties of 10-hour photoperiods for 10, 20, and 30 days at different stages of growth*

PANICLE LENGTH

Group and variety	Average plants per treatment	Average panicle length and plant height of control	Average length of panicle on tallest tillers and height of each plant when covered daily for—								
			10 days beginning—				20 days beginning—			30 days beginning—	
			June 1	June 11	June 21	July 1	June 1	June 11	June 21	June 1	June 11
	Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Sensitive varieties:											
C. I. 81C	12.8	8.9	8.1	7.9	8.0	8.2	7.2	7.1	7.7	7.3	7.3
Caloro	12.4	8.4	7.5	7.4	7.9	7.7	6.9	6.6	7.0	6.7	6.4
Kameji	12.3	7.9	6.1	6.3	6.9	7.0	5.5	5.9	6.4	5.6	6.3
Improved Blue Rose	13.2	9.1	7.2	7.7	7.8	8.4	6.9	7.4	7.3	5.8	7.6
C. I. 4700	16.0	10.3	7.0	8.6	8.9	9.8	7.2	7.3	8.0	7.1	6.8
Average	13.3	8.9	7.2	7.6	7.9	8.2	6.7	6.9	7.3	6.5	6.9
Less sensitive varieties:											
C. I. 6993	5.6	7.1	6.4	6.8	6.7	6.6	6.3	6.8	6.4	5.7	6.6
Shoemed	14.9	10.5	10.0	11.6	10.4	10.3	12.0	10.1	9.7	10.4	9.4
Nira	16.0	11.6	11.7	12.0	10.8	10.9	11.9	11.1	10.5	11.7	10.9
Fortuna	15.9	10.5	10.6	10.5	9.6	10.4	11.5	10.7	10.3	11.2	10.3
Rexoro	15.0	10.8	10.9	11.0	9.8	10.5	11.3	10.7	9.7	10.8	9.4
Average	13.5	10.1	9.9	10.4	9.5	9.7	10.6	9.9	9.3	10.0	9.3

PLANT HEIGHT

Sensitive varieties:											
C. I. 81C	12.8	42.9	34.1	36.9	39.5	41.7	32.9	34.5	38.5	31.1	33.5
Caloro	12.4	39.4	25.5	30.6	35.2	38.9	27.0	28.9	32.4	27.0	29.8
Kameji	12.3	42.1	20.5	26.1	34.4	35.5	22.4	27.4	32.3	23.1	31.3
Improved Blue Rose	13.2	46.1	23.8	29.3	34.2	37.6	28.5	33.8	34.4	24.8	34.0
C. I. 4700	16.0	54.0	25.0	33.1	37.3	44.8	31.3	35.5	39.1	29.7	33.7
Average	13.3	44.9	25.8	31.2	36.1	39.7	28.4	32.0	35.3	27.1	32.5
Less sensitive varieties:											
C. I. 6993	5.6	33.5	28.0	32.8	31.7	33.2	28.2	32.1	31.8	24.8	31.6
Shoemed	14.9	43.0	41.2	40.9	41.6	43.9	42.3	43.3	42.6	41.4	42.0
Nira	16.0	50.9	50.7	50.0	45.6	46.3	51.8	46.2	45.0	45.6	45.8
Fortuna	15.9	46.3	46.5	44.5	42.0	44.4	47.6	45.1	43.5	46.6	42.1
Rexoro	15.0	46.8	47.0	44.8	38.4	36.2	47.9	37.6	36.8	42.2	37.6
Average	13.5	44.1	42.7	42.6	39.9	40.8	43.6	40.9	39.9	40.1	39.8

PLANT HEIGHT

Average plant height, based on the tallest tiller of each plant, showed a marked reduction for the sensitive varieties at the earliest covering periods (table 3). As the date of covering was delayed, there was a gradual increase in plant height, but the latest covering periods still showed an appreciable reduction in height as compared with plants of the normal-day or control plot. The less sensitive varieties showed only slight reductions in plant height at the earliest covering periods, followed by greater reductions as the date of covering was delayed (fig. 2).

In both the sensitive and less sensitive groups, the 10-, 20-, and 30-day covering periods showed essentially the same effect on plant height, except that the effects of the short-day treatments were slightly more intensified for the longer covering periods.

GRAIN AND STRAW WEIGHTS

The average grain and straw weights were determined for the sensitive varieties Caloro, Improved Blue Rose, and C. I. 4700, and for the less sensitive varieties Shoemed, Nira, Fortuna, and Rexoro (table 4). As a group the sensitive varieties showed the greatest re-

TABLE 4.—*Effect on average grain and straw weights in 7 rice varieties of 10-hour photoperiods for 10, 20, and 30 days at different stages of growth*

GRAIN

Group and variety	Average plants per treatment	Average grain and straw weight of control	Average grain and straw weight per plant when covered daily for—								
			10 days beginning—				20 days beginning—			30 days beginning—	
			June 1	June 11	June 21	July 1	June 1	June 11	June 21	June 1	June 11
Sensitive varieties:	*Number*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Caloro	12.4	5.7	1.3	2.3	4.7	6.0	2.7	1.6	3.6	1.3	1.3
Improved Blue Rose	13.2	7.5	.4	1.8	4.0	4.4	1.4	1.9	2.8	.5	2.2
C. I. 4700	16.0	12.0	.4	2.1	4.1	7.6	1.7	2.6	5.3	2.3	1.7
Average	13.9	8.4	.7	2.1	4.3	6.0	1.9	2.0	3.9	1.4	1.7
Less sensitive varieties:											
Shoemed	14.9	7.3	3.4	4.4	3.2	6.0	5.3	4.9	3.9	2.9	1.9
Nira	16.0	7.5	6.6	7.1	5.6	5.9	7.9	5.6	3.6	5.9	4.1
Fortuna	15.9	7.2	5.8	6.5	5.1	6.1	8.4	7.5	6.0	7.2	5.1
Rexoro	15.0	6.5	8.3	6.8	4.1	4.9	7.4	5.2	3.1	6.3	4.2
Average	15.5	7.1	6.0	6.2	4.5	5.7	7.3	5.8	4.2	5.6	3.8

STRAW

Sensitive varieties:											
Caloro	12.9	8.0	5.7	5.3	5.7	8.7	3.3	3.1	3.9	2.1	2.0
Improved Blue Rose	17.2	15.5	8.9	7.5	7.4	11.2	5.8	6.0	6.4	4.1	3.7
C. I. 4700	17.3	26.4	13.1	12.6	14.5	24.4	7.4	7.8	7.8	4.1	4.9
Average	15.8	16.6	9.2	8.5	9.2	14.8	5.5	5.6	6.0	3.4	3.5
Less sensitive varieties:											
Shoemed	15.4	11.8	7.1	6.3	5.5	11.0	8.8	7.2	6.4	5.9	5.9
Nira	16.0	11.2	10.4	10.6	9.4	10.6	13.6	10.6	7.5	10.1	8.4
Fortuna	15.9	8.8	7.4	9.3	6.8	8.5	9.9	10.7	7.9	9.2	7.9
Rexoro	15.0	15.6	18.3	14.8	8.3	7.9	17.2	8.8	6.1	14.4	6.6
Average	15.6	11.9	10.8	10.3	7.5	9.5	12.4	9.3	7.0	9.9	7.2

duction in grain and straw weights at the earliest covering periods, except from the 10-day treatment beginning June 1 for straw weights. As in the case of the other characters studied, the effect was less the later the covering periods were begun. The less sensitive varieties showed only slight reductions in grain and straw weights, as compared with the sensitive varieties, at the earliest covering periods. There was a gradual intensification of the effect as the date of covering was delayed (fig. 2).

SPLIT-DAY TREATMENTS

As shown in table 5, plants subjected to morning and afternoon covering usually headed later than controls. The early-maturing varieties C. I. 6993 and C. I. 81C showed the greatest effect from the split-day treatments and, when covered daily from 8 a. m. to 1 p. m. or from 1 to 6 p. m. for 30 days beginning June 1, headed 19.2 and 12.1 days and 18.5 and 12.0 days later, respectively, than plants of the normal-day treatment. The delay in time of heading was not so marked for the midseason and late varieties Kameji, Nira, Fortuna, and Improved Blue Rose, ranging from 1.3 days earlier to 4.5 days later than the control plants. Rexoro and C. I. 4700, very late-maturing varieties, were only slightly affected by these treatments, ranging from 0.9 days earlier to 1.9 days later in heading than the control plants. The greatest delays in time of heading were for the 30-day covering period.

A rather consistent difference in varietal reaction to morning and afternoon interception of light was evident for the 10-, 20-, and 30-day covering periods ended on July 10. The less sensitive varieties Shoemed, Nira, and Fortuna, when covered from 8 a. m. to 1 p. m. for these periods, headed 1.7 to 11.0 days later than adjacent plants covered from 1 to 6 p. m. Rexoro behaved in the same manner, except that the differences were smaller. The sensitive varieties Caloro, Kameji, and Improved Blue Rose, of similar maturity as Shoemed, Nira, and Fortuna, when covered from 8 a. m. to 1 p. m. for 10, 20, and 30 days, ending July 10, headed 0.9 to 2.4 days earlier than adjacent plants covered from 1 to 6 p. m.; but no consistent differences in time of heading between morning and afternoon treatments appeared for C. I. 81C, C. I. 6993, and C. I. 4700.

The split-day plots, when covered on June 30 or later—including 12 treatments of each day length with a total for each variety of 11 to 38 control plants, 27 to 112 plants covered in the morning, and 28 to 110 plants covered in the afternoon—were compared to determine whether the differences between morning and afternoon light interception were significant statistically. The averages for the factors studied, based on the 12 treatments of each day length, are shown in table 6. While the differences recorded were small, they appear to be significant for some varieties. The sensitive varieties Caloro, Kameji, and Improved Blue Rose headed slightly earlier when covered in the morning than when covered in the afternoon, and the differences appear to be highly significant for each variety. All 5 of the less sensitive varieties and sensitive varieties C. I. 81C and C. I. 4700 headed slightly later when covered in the morning than when covered in the afternoon. The differences for Shoemed, Nira, Fortuna, and Rexoro were highly significant and that for C. I. 81C was significant.

TABLE 5.—*Comparative effect on time of panicle emergence in 10 rice varieties of split-day treatments from 8 a. m. to 1 p. m. and 1 to 6 p. m. for 10, 20, and 30 days at different stages of growth*

Treatment			Average plants per variety	Average period from seeding to first panicle emergence from the boot of each plant											
				Sensitive varieties						Less sensitive varieties					
Date ended	Duration	Clock time		C. I. 81C	Caloro	Kameji	Improved Blue Rose	C. I. 4700	Average	C. I. 6993	Shoemed	Nira	Fortuna	Rexoro	Average
	Days		*Number*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
Control			29.9	107.1	114.2	121.2	131.0	146.0	123.9	85.5	115.7	124.6	124.8	145.8	119.3
June 10	10	8 a. m.–1 p. m.	14.0	110.6	115.4	123.1	131.9	146.2	125.4	91.8	116.6	126.0	125.2	146.3	121.2
	10	1–6 p. m.	13.6	109.5	113.8	123.3	131.8	146.5	125.0	90.7	115.3	128.1	125.0	145.3	120.9
June 20	10	8 a. m.–1 p. m.	15.0	112.4	114.6	122.2	131.7	145.6	125.3	92.5	117.0	124.3	124.9	146.1	121.0
	10	1–6 p. m.	14.2	110.2	115.7	122.2	131.8	146.0	125.2	89.6	116.7	124.6	124.3	145.6	120.2
June 30	10	8 a. m.–1 p. m.	15.1	111.8	118.3	122.1	131.4	146.0	125.9	88.5	120.0	124.4	125.3	145.8	120.8
	10	1–6 p. m.	16.8	110.1	118.4	122.4	131.2	145.1	125.4	87.6	115.3	124.6	124.6	144.9	119.4
July 10	10	8 a. m.–1 p. m.	15.4	108.1	118.2	121.8	129.7	146.3	124.8	86.3	117.0	127.6	125.6	147.1	120.7
	10	1–6 p. m.	14.5	108.2	120.0	123.8	131.8	146.5	126.1	85.0	114.4	123.4	123.5	145.7	118.4
June 20	20	8 a. m.–1 p. m.	14.7	113.7	117.1	123.8	132.7	145.4	126.5	99.0	118.2	126.5	125.8	146.3	123.2
	20	1–6 p. m.	13.9	115.3	116.6	123.7	132.6	145.6	126.8	98.6	120.1	125.5	126.6	146.4	123.4
June 30	20	8 a. m.–1 p. m.	14.3	113.6	117.6	122.2	132.4	145.9	126.3	89.0	121.2	126.3	125.3	145.7	121.5
	20	1–6 p. m.	15.1	113.1	118.4	122.5	132.0	145.8	126.4	89.6	117.3	124.6	124.8	145.1	120.3
July 10	20	8 a. m.–1 p. m.	14.5	113.6	121.7	122.9	131.6	146.9	127.3	87.4	125.2	128.9	127.9	147.0	123.3
	20	1–6 p. m.	13.9	111.6	122.7	125.3	132.7	147.0	127.9	89.8	114.2	124.2	124.4	145.9	119.7
June 30	30	8 a. m.–1 p. m.	13.7	119.2	118.9	124.7	133.6	146.8	128.6	104.7	124.1	127.0	127.0	147.2	126.0
	30	1–6 p. m.	13.8	119.1	118.8	124.8	132.7	146.6	128.4	104.0	120.0	126.0	126.1	145.2	124.3
July 10	30	8 a. m.–1 p. m.	15.7	119.0	121.9	124.0	132.2	146.5	128.7	94.6	126.6	129.0	127.4	147.7	125.1
	30	1–6 p. m.	14.7	114.1	122.8	125.7	133.6	146.5	128.5	90.6	116.7	125.2	125.7	146.9	121.0

The split-day treatments usually resulted in a slight reduction in number of tillers and panicles, length of panicles, plant height, and grain and straw weights. The later in the growth period the plants were covered, the greater were the reductions in the characters studied. The effect of the split-day treatments on these characters was not so consistent as it was on the time of heading.

All varieties showed a greater reduction in the number of tillers and panicles from afternoon than from morning light interception, except C. I. 4700 and Nira. The differences in number of tillers and

TABLE 6.—*Average effect on the characters studied of split-day treatments from 8 a. m. to 1 p. m. and from 1 to 6 p. m. as compared with normal-day plots*

AVERAGE NUMBER OF DAYS FROM SEEDING TO PANICLE EMERGENCE

Duration of treatment	Sensitive varieties						Less sensitive varieties					
	C. I. 81C	Caloro	Kameji	Improved Blue Rose	C. I. 4700	Average	C. I. 6993	Shoemed	Nira	Fortuna	Rexoro	Average
Normal day	107.1	114.2	121.2	131.0	146.0	123.9	85.5	115.7	124.6	124.8	145.8	119.3
8 a. m.–1 p. m.	114.2*	119.4**	122.9**	131.8**	146.4	126.9	91.9	122.4**	127.2**	126.4**	146.7**	122.9
1–6 p. m.	112.7	120.3	124.1	132.4	146.2	127.1	91.0	116.4	124.7	124.9	145.6	120.5

AVERAGE NUMBER OF TILLERS PER PLANT

Normal day	4.61	2.85	2.78	3.17	4.50	3.58	2.55	2.97	1.97	1.91	1.90	2.26
8 a. m.–1 p. m.	3.84	2.83*	2.51	2.77	4.48	3.29	2.60	2.46	1.85	1.82	1.92	2.13
1–6 p. m.	3.81	2.40	2.18	2.63	4.53	3.11	2.44	2.23	1.87	1.70	1.74	2.00

AVERAGE NUMBER OF PANICLES PER PLANT

Normal day	4.43	2.73	2.78	3.11	4.50	3.51	2.55	2.84	1.97	1.91	1.90	2.23
8 a. m.–1 p. m.	3.76	2.81*	2.51	2.77*	4.48	3.27	2.50	2.43	1.83	1.82	1.91	2.10
1–6 p. m.	3.71	2.38	2.18	2.61	4.53	3.08	2.28	2.20	1.86	1.70	1.74	1.96

AVERAGE PANICLE LENGTH (INCHES)

Normal day	8.9	8.4	7.9	9.1	10.2	8.9	7.1	10.5	11.6	10.5	10.8	10.1
8 a. m.–1 p. m.	8.4	8.2	7.7**	8.7	10.1	8.6**	6.8	10.7	11.3	10.4	10.5	9.9
1–6 p. m.	8.7	8.3	8.1	8.9	10.3	8.9	6.8	10.6	11.2	10.3	10.5	9.9

AVERAGE PLANT HEIGHT (INCHES)

Normal day	42.9	39.4	42.1	46.1	54.0	44.9	33.5	43.0	50.9	46.3	46.8	44.1
8 a. m.–1 p. m.	42.2	39.3	39.2**	43.7*	53.2	43.5	31.1	44.8*	50.5	46.6	45.9	43.8
1–6 p. m.	42.2	39.7	41.4	44.8	53.5	44.3	32.4	42.5	50.0	46.2	46.0	43.4

AVERAGE GRAIN WEIGHT PER PLANT (GRAMS)

Normal day	------	5.7	------	7.5	12.0	8.4	------	7.3	7.5	7.2	6.5	7.1
8 a. m.–1 p. m.	------	5.52	------	5.88	11.23*	7.5	------	6.36	5.98	5.72	5.53	5.9
1–6 p. m.	------	5.05	------	5.50	12.29	7.6	------	5.08	6.86	5.78	5.91	5.9

AVERAGE STRAW WEIGHT PER PLANT (GRAMS)

Normal day	------	8.0	------	15.5	26.4	16.6	------	11.8	11.2	8.8	15.6	11.9
8 a. m.–1 p. m.	------	8.82	------	12.30	27.13	16.1	------	10.10*	9.74	7.73	14.69	10.6
1–6 p. m.	------	7.91	------	12.99	28.58	16.5	------	8.61	10.59	7.34	13.53	10.0

[1] *=Significant differences between treatments from 8 a. m. to 1 p. m. and those from 1 to 6 p. m.; **=highly significant differences between treatments from 8 a. m. to 1 p. m. and those from 1 to 6 p. m.

panicles for Caloro and in number of panicles for Improved Blue Rose appear to be significant. When the eight varieties that showed the greatest reductions from afternoon covering were analyzed as a group, the difference between morning and afternoon covering, both in number of tillers and in number of panicles, seemed highly significant.

The average length of panicle of the five sensitive varieties was shorter when the plants were covered in the morning than when they were covered in the afternoon, and this difference appears to be highly significant for Kameji and for the average of the five varieties. In the less sensitive varieties the differences in length of panicle were not significant, although the panicles of Shoemed, Nira, and Fortuna were somewhat longer from morning than from afternoon light interception.

In plant height, four of the sensitive varieties were shorter from morning than from afternoon covering, and the differences for Kameji and Improved Blue Rose apparently were highly significant. The average difference in plant height between morning and afternoon covering for Caloro, Kameji, Improved Blue Rose, and C. I. 4700 as a group appears to be highly significant. The less sensitive varieties Shoemed, Nira, and Fortuna were taller when covered in the morning than in the afternoon, and as a group the average difference was apparently significant.

Weights of grain and straw per plant were obtained for seven varieties. For C. I. 4700 there was what appears to be a significant decrease in grain weight per plant from morning as compared with afternoon covering. The increase in straw weight for Shoemed from morning as compared with afternoon covering apparently was significant. None of the other varieties showed differences in grain or straw weight, between morning and afternoon covering, that appeared to be significant.

DISCUSSION

In general, the results show that varieties subjected to a daily 10-hour photoperiod usually headed before the controls and that varieties under the split-day treatments headed at about the same time as or later than the controls. Kondo and his associates (*9*, *10*), and others have reported similar results with rice in Japan, and Garner and Allard (*4*, *5*, *6*) with other crops in this country.

The two periods of heading for the sensitive varieties Caloro, Kameji, Improved Blue Rose, and C. I. 4700 were apparently due to the fact that very little tillering had occurred by the time the early covering treatments were concluded. Kondo et al. (*9*) showed that individual tillers of the same plant react independently of one another when subjected to different day lengths. In this study most of the tillers developed after the covering periods ended, so that it is reasonable to assume that the treatments had no effect on the time of heading of such tillers.

The data presented on time of panicle emergence indicate that flower-bud differentiation in the sensitive varieties was initiated by a treatment consisting of a daily 10-hour photoperiod for 10 days beginning as early as 30 days after seedling emergence. On the less sensitive varities, however, except C. I. 6993, this treatment had little if any effect on bud differentiation. This indicates that the less sensitive varieties must reach a certain stage of development before the short-day treatments have any effect on time of flower-bud differentiation.

The reaction to the short-day treatment of the varieties grown appears to be associated with the latitude to which they are native. The sensitive varieties were native to or were developed from varieties native to a latitude above 30° north; the less sensitive varieties were native to a latitude nearer the Equator. The sensitive varieties showed the maximum effect of the short-day treatments on the characters studied for the earliest covering date, with a less marked effect for successively later dates of covering.

The sensitive varieties Caloro and Kameji are of Japanese origin, and Improved Blue Rose probably was selected from a hybrid in which one of the parents was a Japanese variety. C. I. 81C and C. I. 4700 are medium-grain varieties that tiller profusely. These varieties were introduced from the Philippine Islands, but from their reaction to the short-day treatments and other characteristics, they might have been introduced into the Philippines from China. The less sensitive varieties Shoemed, Nira, and Rexoro were also selected from varieties introduced from the Philippine Islands. Fortuna was selected from an introduction from Formosa, and C. I. 6993 is of Japanese origin. As a group, these varieties showed very little effect of the short-day treatments for the earliest covering periods but a more marked effect as the date of covering was delayed.

SUMMARY

Ten varieties of rice, growing under field conditions, were subjected to short-day treatments for 10, 20, and 30 days at different stages of development. The following treatments, in addition to the normal day length, were used: (1) A continuous 10-hour daylight period; (2) approximately 10 hours of daylight with a 5-hour covering period in the morning; and (3) approximately 10 hours of daylight with a 5-hour covering period in the afternoon.

The varieties, based on their reactions to the covering periods, were divided into "sensitive" and "less sensitive" groups. The sensitive varieties, when subjected to a daily 10-hour photoperiod at the earliest covering dates, showed a marked decrease in (1) the number of days required from seeding to first heading, (2) number of tillers and panicles, (3) length of panicle, (4) height of plant, and (5) grain and straw weights. As the date of covering was delayed, the effects became gradually less marked. The less sensitive varieties showed little or no effect on these characters for the earliest covering periods, followed by a gradual intensification of the effect for later covering dates.

Although differences were small, plants subjected to morning and afternoon covering usually headed later than the controls. The sensitive varieties tended to head later from afternoon than from morning covering, while the less sensitive varieties tended to head later from morning covering. The data on length of panicle and plant height were less consistent than for date of heading, but in most cases the sensitive varieties produced the longest panicles and the tallest plants when covered in the afternoon, while the less sensitive varieties produced the longest panicles and the tallest plants when covered in the morning. Both the sensitive and the less sensitive varieties showed a reduction in number of tillers and panicles from afternoon as compared with morning covering. No consistent differences between morning and afternoon covering were recorded for grain and straw weights.

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THE COMPOSITION AND PALATABILITY OF SOME COMMON GRASSES[1]

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INTRODUCTION

In 1928 a project was organized by the Chemistry Department of the Massachusetts Agricultural Experiment Station entitled, "Studies in the Chemistry of Pasture Grasses." One phase of this project involved a study of the chemical composition of different species of grasses at the grazing stage. This particular study was undertaken because a search of the literature had disclosed a scarcity of information on the chemical composition at the grazing stage of individual species of the grasses commonly grown in the northeastern part of the United States. The study was continued over a period of 7 years (1931–37 inclusive). One progress report (*1*)[2] giving results for the years 1931, 1932, and 1933 has already been published. This paper is the final report and sets forth the results for the entire 7-year period, the earlier published results for 1931, 1932, and 1933 having been combined with those for 1934 to 1937.

Although the chemical composition of grasses has been widely studied, one or more of three circumstances has rendered the findings inapplicable to the present work: (1) The species used differed from those included in this study; (2) the analyses were made when the grasses were too mature to be considered as typical of good grazing, generally at or near the blossom stage; or (3) the studies were made on mixed herbage. A report of a few analyses of *Poa pratensis* by Pammel, Weems, and Lamson-Scribner (*7*), and more recently the work of Grunder (*5*) on *Trifolium repens*, are all that seem to have a direct bearing on this study.

EXPERIMENTAL METHODS

Six species of grasses have been grown as pure or practically pure stands, and their chemical composition has been determined by monthly sampling and analysis throughout the growing season (May–September) of each of the years indicated. In addition, one other species of grass and two species of legumes have been similarly studied during several seasons of the period indicated. Vitamin A assays of the fresh grasses have been made in several seasons, and the palatability of the grasses to cows has been studied by means of actual grazing tests.

Two separate tracts of land were chosen for the investigation. Tract No. 1 was utilized from 1931 to 1936 inclusive for studies of composition, and in 1937 and 1938 for palatability tests. From 1931

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[2] Italic numbers in parentheses refer to Literature Cited, p. 347.

to 1934 inclusive the grasses were grown without fertilizer other than that residual in the soil. In 1934, 1935, and 1936 a complete 8–6–6 fertilizer was applied at the rate of 400 pounds per acre at the beginning of the growing season.

Tract No. 2 was seeded in 1933, but samples were not taken until 1935 because flooding and winter-killing had necessitated complete reseeding. The analytical studies were continued through 1935, 1936, and 1937, and in 1938 palatability tests were conducted. Fertilizer was not applied to this set of plots at any time during the investigation. Analyses of the soils of both tracts are given in table 1; the principal differences are the somewhat larger amount of fine material and the very much larger amounts of organic matter and nitrogen in the soil of tract 2.

TABLE 1.—*Analysis of the air-dry soils* [1]

Tract and soil profile	Fine soil (1 mm or less)	Organic and volatile matter	Total nitrogen	Total phosphorus	Total potassium	Total calcium	Available phosphorus	pH
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Parts per million*	
Tract 1:								
Surface soil	92.17	5.05	0.14	0.18	2.01	1.43	154	6.05
Subsoil	99.33	2.63	.04	.03	1.85	1.44	7	5.50
Tract 2:								
Surface soil	98.50	12.87	.41	.12	1.86	1.17	73	5.52
Subsoil	90.90	2.89	.06	.03	2.35	1.44	11	5.65

[1] All determinations except available phosphorus were made by the methods of the Association of Official Agricultural Chemists (*2*). Available phosphorus was determined by Truog's method (*8*).

The grasses and legumes chosen for the investigation were: Kentucky bluegrass (*Poa pratensis*), also called Junegrass; orchard grass (*Dactylis glomerata*); redtop (*Agrostis alba*); Rhode Island bent (*Agrostis capillaris*), also called colonial bent; timothy (*Phleum pratense*), also called herd's grass; sheep fescue (*Festuca ovina*); sweet vernal grass (*Anthoxanthum odoratum*); white Dutch clover (*Trifolium repens*); and Ladino clover (*Trifolium repens*).

Each series of plots was replicated once, making a total of 16 plots in the first series and 18 in the second. Each plot was 3½ feet wide by 62 feet long, and had an area of approximately one two-hundredth of an acre. To prevent mixing of the species and to facilitate control of weeds, paths 1 foot wide were maintained between individual plots and a border of fallow soil 3 feet wide was left along the margins of each tract. Seed was sown in the late summer (except for a few cases of reseeding) without a nurse crop and the plots were kept free from weeds by hand labor. A reasonable degree of success was attained in keeping pure the stands of the individual species.

Samples were taken by means of a lawn mower with a grass catcher attached whenever the grass reached a height of 3 to 4 inches, so that intervals between samplings varied with species and season of the year. Whenever possible at least one sample a month was taken from each species; wherever rate of growth necessitated taking more than one sample in a month from any species, yield and moisture content were determined on the additional samples, and each sample was composited with the sample already taken from the same plot.

Analyses were made for moisture in the fresh grass, and for total nitrogen, crude fiber, ether extract, total ash, acid-soluble ash, calcium phosphorus, and magnesium in the dry matter. Potassium was determined in the samples for 1931, 1932, and 1933, but because of its minor significance in the nutrition of grazing animals, it was not determined from that time onward.

All analyses except those for calcium, phosphorus, and magnesium were made according to the official methods of the Association of Official Agricultural Chemists (*2*).[3] Calcium and magnesium were determined by a modification of McCrudden's method (*6*), and phosphorus by the method of Fiske and Subbarow (*4*). Vitamin A was determined by biological assay with white rats, on a much smaller number of samples (51) taken for the most part independently of the main investigation.

During May and June of 1937 and 1938 a series of tests of the palatability of seven of the species was conducted with mature Jersey and Guernsey cows in milk at the time. The entire tract of each series of plots was fenced off, the plots were conspicuously numbered, and a tub of water was placed at a convenient point within the enclosure. Two cows were used at a time. They were turned into the enclosure soon after 8 a. m. and taken out again shortly before noon. There was sufficient grass so that each trial extended over 2 such half days.

A complete record of the length of time spent by each cow in grazing each species was obtained by an attendant who noted the exact time that a cow started and stopped grazing on any particular plot. Lulls in grazing, after which the cow resumed grazing on the same plot, were recorded as carefully as shifts from plot to plot.

PRESENTATION OF RESULTS

CHEMICAL ANALYSES

A total of 300 samples of the several species was taken, but this number was reduced for analysis to 263 by the compositing of certain samples.

The results on the first six species listed in table 2 form the principal basis for discussion. Such information as was obtained on the last three species has been appended as a supplement to the more complete report on the first six. There are two reasons for this procedure: (1) The much larger number of samples from individual species in the first group, and (2) each and every year and a majority of months are represented in the data from the first group, whereas for unforeseen or unavoidable reasons this was not true for any of the three species in the second group.

In this study there were representatives of two great classes of herbage, the so-called top and bottom grasses, or more specifically those grasses more suitable for hay as contrasted with those more suitable for grazing. Some interesting differences are apparent in the composition of the species in these two classes. The top grasses were decidedly more succulent than the bottom grasses; they averaged about 2.5 percent less fiber and contained larger amounts of

[3] Grateful acknowledgment is made of the services of J. W. Kuzmeski and A. F. Spelman, who made the determinations of crude fiber and ether extract under the direction of Philip H. Smith, chief chemist of the feed control laboratory of this station.

ether extract, soluble ash, calcium, magnesium, and vitamin A (carotene). These differences probably are due in considerable measure to differences in stage of maturity and relative leaf area of the two classes of grass at a given height; they have a bearing on grazing practice that should not be lost sight of.

TABLE 2.—*Composition of 7 species of grass and 2 legumes, seasons of 1931–37*

Species	Samples	Moisture in the fresh grass	Composition of dry matter								Vitamin A equivalent per pound of dry matter
			Nitrogen[1]	Crude fiber	Ether extract	Total ash	Acid-soluble ash	Calcium	Phosphorus	Magnesium	
	No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*International units*
Top grasses:											
Orchard grass	34	76.2	2.9	23.0	4.5	12.7	8.4	0.63	0.58	0.32	152,000
Redtop	36	74.0	3.0	21.9	4.2	10.6	6.8	.68	.39	.27	133,000
Timothy	36	74.2	2.9	20.6	3.9	9.5	6.3	.59	.40	.25	162,000
Bottom grasses:											
Kentucky bluegrass	39	69.6	3.0	23.6	3.4	9.0	5.8	.51	.42	.23	101,000
Rhode Island bent	37	70.6	3.1	21.7	3.7	10.3	6.2	.64	.40	.23	132,000
Sheep fescue	39	67.1	2.7	26.8	3.3	8.4	5.0	.43	.36	.16	85,000
Sweet vernal grass	14	77.9	3.2	17.6	4.7	10.0	6.8	.64	.38	.27	118,000
White Dutch clover	20	82.6	4.6	14.4	3.1	12.3	9.9	1.61	.45	.29	[2]
Ladino clover	8	83.7	4.3	13.7	2.5	13.5	8.8	1.90	.37	.42	[2]

[1] Reported as nitrogen rather than as protein because not all the nitrogen is in the form of protein; the amount of nonprotein nitrogen is small—10 percent or less.
[2] Not determined.

Nitrogen differences between species were small for the most part, and the same was true of phosphorus. The high value for phosphorus in orchard grass noted in the earlier report (*1*), while still persisting in the samples grown on soil of tract 1, was not noted in the samples from soil of tract 2. This may be due to the fact that there was about twice as much available phosphorus in the soil of tract 1 as in that of tract 2 (see table 1). It has been suggested that possibly the ability to utilize additional phosphorus may be a characteristic peculiar to this species of grass.

There seems to be a rather definite relation between the amount of fiber in the several species and their breaking strength. Beaumont, Stitt, and Snell (*3*), of this station, have reported breaking strength for four of the six species represented here. Their values, arranged in order of increasing strength, are compared with those for fiber content in table 3. Except that the timothy had a little less fiber than the

TABLE 3.—*Breaking strength compared with fiber content of four of the species of grasses included in the test*

Species	Breaking strength[1]	Fiber content
	Grams	*Percent*
Redtop	52.9	21.9
Timothy	58.6	20.6
Kentucky bluegrass	92.6	23.6
Sheep fescue	147.9	26.8

[1] Grams per millimeter of perimeter; average of 50 determinations.

redtop, the two sets of values are in the same order; i. e., the higher the content of fiber the higher the breaking strength, which is what would naturally be expected.

The proportion of soluble ash to total ash was rather constant (table 2) the variation being only from 66.2 percent in orchard grass to 59.4 percent in sheep fescue; although there were some exceptions, in general the higher the percentage of soluble ash the greater the proportion of the total ash it constituted. As in the earlier trials (*1*), the two members of the bent family (redtop and Rhode Island bent) had the highest calcium values of the group, but contrary to earlier results, the value for redtop was higher than that for Rhode Island bent.

In general, the constitutents that varied significantly from one species to another were: Moisture, in the fresh grass; and, in the dry matter, crude fiber, ether extract, soluble ash, calcium, and magnesium. With minor exceptions phosphorus and nitrogen did not vary significantly.

In addition to the six species just discussed, three other species—one grass and two legumes—were studied, but in less detail, as already noted. The data are too incomplete to warrant statistical analysis, but they are given at the bottom of table 2 for such information as they may furnish.

In the limited number of samples available sweet vernal grass averaged higher in moisture, nitrogen, and ether extract, and lower in crude fiber than any of the other six species of grass. It was also quite high in soluble ash and magnesium, and was in a class with redtop and Rhode Island bent in its content of calcium.

White Dutch clover was decidedly more succulent than any of the grasses, its nitrogen (protein) content, like that of all legumes, was high (equivalent to 27 percent of protein in the dry substance); its fiber content was about 7 percent less than that of timothy, the best grass in this respect; its soluble-ash content of almost 10 percent was approached only by that of orchard grass; its calcium content was nearly 2½ times as much as that of redtop, the grass with the highest calcium value; its phosphorus content was exceeded only by that of orchard grass, and the same was true for magnesium. Only in ether extract was it lower than the grasses, containing less than sheep fescue, the lowest grass in this respect.

The small number of samples of Ladino clover (a giant variety of *Trifolium repens*) show its composition to be very similar in most respects to that of the dwarf white Dutch variety.

STATISTICAL ANALYSES

In the course of the statistical studies some interesting correlations were observed; those of special significance were between:

Moisture and nitrogen	$r=0.59\pm0.03$
Ether extract and soluble ash	$r=.55\pm.03$
Soluble ash and phosphorus	$r=.74\pm.20$
Calcium and magnesium	$r=.70\pm.02$

There was one significantly negative correlation, that between nitrogen and crude fiber, $r=0.62\pm0.03$.

PALATABILITY TRIALS

Palatability trials with five cows extended over 105 hours of potential grazing time and 54 hours of actual grazing time. A summary of the results of these trials, classified according to individual preference for the several species of grass, as well as the average preference for the entire series of trials, is presented in table 4. The cows showed a decided preference for timothy. In order of preference orchard grass, redtop, Rhode Island bent, and sweet vernal grass ranked so close together (16 to 17.5 percent) that probably the small differences between them were not significant. Bluegrass, however, was grazed less than 10 percent of the time, and sheep fescue was practically untouched.

Separation of the results into groups for first and second day, for first, second, and third trials, and for the two series of plots shows that the trends of preference noted for the results as a whole persisted remarkably all through these smaller groups.

Some variation in individual preference was noted, but the general trend was unmistakable, especially as to the best-liked and least-liked species. In palatability timothy was at or near the top; redtop was near the top; bluegrass was near the bottom—not higher than fifth place in any case—and fescue was consistently in last place.

TABLE 4.—*Summary of results of the grazing trials classified according to individual preference for the several species*

Cow No.	Total grazing time	Kentucky bluegrass		Orchard grass		Redtop		Rhode Island bent		Sheep fescue		Sweet vernal grass		Timothy	
		Grazing time	Proportion of total	Grazing time	Proportion of total	Grazing time	Proportion of total	Grazing time	Proportion of total	Grazing time	Proportion of total	Grazing time	Proportion of total	Grazing time	Proportion of total
	Min.	*Min.*	*Pct.*	*Min.*	*Pct.*	*Min.*	*Pct.*	*Min.*	*Pct.*	*Min.*	*Pct.*	*Min.*	*Pct.*	*Min.*	*Pct.*
760	787	90	11.4	142	18.0	151	19.2	147	18.7	3	0.4	80	10.2	174	22.1
806	442	38	8.6	78	17.7	98	22.2	65	14.7	1	.2	83	18.8	79	17.9
607	198	15	7.6	46	23.2	25	12.6	21	10.6	0	....	49	24.8	42	21.2
665	863	28	3.2	105	12.2	112	13.0	131	15.2	15	1.7	217	25.1	255	29.6
687	950	145	15.3	196	20.6	166	17.5	159	16.7	7	.7	89	9.4	188	19.8
Total	3,240	316	....	567	.....	552	.....	523	.....	26	....	518	.....	738	.....
Weighted average	.....	.....	9.8	.....	17.5	.....	17.0	.....	16.1	.....	.8	.....	16.0	.....	22.8

On the basis of the preference shown by the cows as a group the rating of the grasses is without exception in the order of their vitamin A (carotene) content, and with one exception in the order of their succulence (moisture content). In general also the cows preferred those with a relatively high content of ether extract, soluble ash, and magnesium, and with a low content of fiber. Nitrogen (protein) content of the grasses apparently had little if any relation to their palatability.

The observation of some investigators that redtop lacks palatability does not agree with the rating it received in these tests. The discrepancy probably is due to the fact that in these trials it never reached the stage where it developed woody stolons.

SUMMARY

This is the final report of a 7-year investigation into the chemical composition and palatability to cows of certain grasses and legumes grown as practically pure stands. The species studied were: Kentucky bluegrass, orchard grass, redtop, Rhode Island bent, sheep fescue, timothy, sweet vernal grass, white Dutch clover, and Ladino clover.

In the main investigation 300 samples, reduced by compositing to 263, were analyzed. In addition, 51 biological assays were made for vitamin A, and palatability tests with 5 cows extended over 105 hours of potential grazing time and 54 hours of actual grazing time.

Considerable species differences were noted in the several constituents except nitrogen and phosphorus [4]; these differences for the most part were more obvious between the two groups of grasses (top and bottom) than between the individuals within a group. Relatively the greatest group differences were in vitamin A (carotene), magnesium, soluble ash, and ether extract, a reflection probably of greater leaf area in the top grasses. The composition of the two legumes was in rather sharp contrast to that of the grasses. Highly significant correlations were noted between certain of the constituents.

Cows used in palatability tests showed a definite preference for species high in moisture and carotene and low in fiber. The nitrogen (protein) content of the grasses apparently had little if any relation to their palatability.

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[4] One species (orchard grass) had a much higher phosphorus content than the others under certain circumstances.

THE PROTEINS OF VARIOUS TREE SEEDS[1]

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INTRODUCTION

The fact that acorns, ironwood seed and elm seed are used as food by wild animals, and to some extent by domestic animals, has prompted this investigation to determine their protein content. Several feeding experiments have been conducted with acorns, but, so far as the writers are aware, no study has been made of the nitrogenous constituents, particularly the protein fractions, of any of these typical tree seeds.

This paper describes a peptization study of the proteins of ironwood seed, elm seed, and several varieties of acorns, the isolation of their major protein fractions, and a study of these proteins according to the method of Van Slyke (*10*).[2]

MATERIALS AND METHODS OF EXPERIMENTATION

The varieties of tree seeds studied are listed according to the classification of Rosendahl and Butters (*7*).

Beech family:
- Black oaks:
  - Northern red oak (*Quercus borealis*).
  - Red oak (*Quercus borealis* var *maxima*).
  - Northern pin oak (jack oak) (*Quercus ellipsolidalis*).
- White oaks:
  - White oak (*Quercus alba*).
  - Northern bur oak (*Quercus macrocarpa* var. *olivaeformis*).

Elm family:
- American elm (*Ulmus americana*).

Birch family:
- Hop-hornbeam or ironwood (*Ostrya virginiana*).

Collections of the various seeds were made during the seasons of 1933, 1936, and 1937, and the material was dried at room temperature. The husks or shells were removed and the seeds ground in a burr mill. The meal was treated in a Soxhlet extractor with naphtha gasoline to remove the fat. The extracted seed meal was dried in an oven at 55° C. and at atmospheric pressure, and further ground in a ball mill until all the material passed through a 100-mesh sieve.

The fat-extracted material will be referred to in this paper as the seed meal. The percentage of fat was determined in the Bailey-Walker apparatus with ether as a solvent. The seed meal was analyzed for moisture and ash by standard methods. Total nitrogen was determined on the seed meal by the Kjeldahl-Gunning-Arnold method, and calculated on the ash- and moisture-free basis.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 355.

EXPERIMENTAL DATA

PEPTIZATION STUDIES ON THE SEED PROTEINS

METHODS

The methods described for this division of the experimental work have been developed on the basis of the general classification given for proteins.

A. Duplicate 2-gm. samples of seed meal were weighed out and transferred to 100-ml. pyrex centrifuge tubes and suspended in 25 ml. of distilled water. This was stirred with a glass rod for 20 minutes and then centrifuged until the liquid was clear. The clear peptizates were decanted into 800-ml. Kjeldahl flasks. A second and a third successive extraction were made in the same manner and the three peptizates were combined for the determination of total nitorgen. It is recognized that salts were present in the meals and may have slightly altered the peptization values. Since the concentrations of these salts in the water range from 0.58 to 0.18 percent as calculated from the ash determination, and since the procedure detailed in paragraph B results in additional protein, the results obtained here are reported as the water-soluble nitrogen fraction.

B. The residues in the 100-ml. centrifuge tubes, after the water-soluble protein had been removed, were next extracted with a 5-percent solution of C. P. potassium chloride in distilled water. This solution has a pH value of 6.78. Three extractions were made according to the procedure described in paragraph A. This is reported as the nitrogen soluble in saline solution.

C. The residues in the 100-ml. centrifuge tubes from paragraph B were extracted with 70-percent alcohol at 65° to 70° C., according to the procedure described in paragrahp A. This is reported as the alcohol-soluble nitrogen.

D. The residues, after fractions A, B, and C of proteins had been removed, were extracted with a 0.2-percent solution of potassium hydroxide. Three extractions were made exactly as described in paragraph A. This fraction is reported as the alkali-soluble nitrogen.

E. The nitrogen in the residues from paragraph D was determined by the Kjeldahl-Gunning-Arnold method and is listed as the residual nitrogen.

RESULTS

The results of the analyses of the seeds made according to the methods outlined above, are given in table 1.

TABLE 1.—*Analysis of the ground tree seeds of various crops*

Seed crop	Fat in dry, ground seed	Seed meal			Proportion of total nitrogen [2]—					Total nitrogen recovery
		Moisture [1]	Ash [1]	Total nitrogen [2]	Water-soluble	Soluble in saline solution	Alcohol-soluble	Alkali-soluble	Residual	
	Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
Elm, 1936	33.55	6.70	7.30	11.55	35.30	46.30	0.70	12.50	5.60	100.40
Ironwood:										
1933				3.17	38.35	35.92	2.28	8.82	13.87	99.24
1937	19.21	6.00	4.65	2.69	12.43	15.94	4.27	38.58	29.72	100.94
White oak, 1936	7.94	3.05	2.65	2.14	21.31	2.58	4.64	40.83	31.29	100.65
Northern bur oak, 1936	7.86	5.80	2.93	1.68	28.62	2.81	5.24	42.98	18.71	98.40
Northern red oak, 1937	20.56	5.18	3.48	1.47	9.85	1.74	6.56	56.22	25.71	100.08
Red oak, 1937	11.60	4.53	3.33	1.52	15.98	1.38	5.84	34.98	41.48	99.66
Northern pin oak, 1937	20.00	5.02	2.22	2.09	6.68	2.41	6.15	58.77	26.31	100.32

[1] Fat-free basis.

[2] Fat-, moisture-, and ash-free basis.

ISOLATION OF PROTEINS FROM THE PREPARED SEED MEAL

Methods

The protein in the seed meal from the elm seed, ironwood seed, white oak, northern bur oak, and northern red oak was fractioned into albumin, globulin, prolamin, and glutelin by peptization in exactly the same manner as described in paragraphs A, B, C, and D above. Ten-gram samples of seed meal, 250-ml. centrifuge tubes, and 250-ml. portions of extracting solutions were used.

A. For the isolation of the albumin fractions from the different meals, the pH of minimum solubility was determined. This was made by the addition of varying amounts of 50 percent acetic acid to a series of tubes of peptizates (pH range from 5.4 to 2.7), and the solutions were boiled for 20 minutes. The material was centrifuged and the unprecipitated nitrogen was determined on aliquots of the clear liquid by the Kjeldahl method. The pH at which the precipitation was most complete was taken as the pH of minimum solubility.

Large volumes of the albumin peptizates were adjusted to the pH of minimum solubility, the protein was coagulated, and then separated from the mother liquors by centrifugation. The proteins were dried with 65-percent, 75-percent, 85-percent, and 95-percent alcohol, used in turn, and finally with anhydrous acetone. The acetone was removed by drying the preparations in an oven at 55° C.

B. The globulins were precipitated from the salt peptizates by dialysis in cellophane tubes against tap water for 12 hours and finally against distilled water for about 24 hours. The proteins were separated from the mother liquors and dried as described in paragraph A.

C. The alcohol extract was diluted with a large volume of water containing a little sodium chloride. A small precipitate resulted which was again dissolved in aqueous alcohol and precipitated. The yield was not enough to permit further study.

D. The pH at which the glutelins were most completely precipitated from the alkaline extracts was determined in the same manner as for the albumin described in paragraph A, except that heating was not necessary. The pH of minimum solubility of the protein is given in table 2. Large volumes of peptizates were adjusted to the pH of

Table 2.—*Minimum solubility of proteins*

Seed meal	Protein	pH range	Seed meal	Protein	pH range
Ironwood	Albumin	3.9–3.4	Northern red oak	do	4.4–3.5
	Glutelin	4.2–3.5	Elm	Albumin	3.8
White oak	Glutelin	4.7–3.9		Glutelin	4.5–3.7
Northern bur oak	do	4.3–3.6			

minimum solubility of the protein by the addition of 50-percent acetic acid and the protein separated from the mother liquors and dried according to the method described in paragraph A.

E. No attempt was made to study the nature of the nitrogen in the residue.

Results

Elm seed and ironwood seed.—The albumin, globulin, and glutelin fractions behaved normally when the above-described methods of

isolation were employed, but the prolamin fractions were so small that their isolation would have been difficult, if not impossible.

Acorns.—The major protein, glutelin, was isolated from white oak, northern bur oak, and northern red oak by the method described in paragraph D. All yields are given in table 3.

TABLE 3.—*Protein isolation yields from various seed meals*

Seed meal	Fraction	Protein yield	Seed meal	Fraction	Protein yield
Ironwood:		*Percent*	Elm:		*Percent*
1933	Albumin	1.61	1934	Albumin	3.65
	Globulin	2.00		do	7.00
	Glutelin	1.17	1936	Globulin	24.30
1937	Albumin	1.22		Glutelin	13.40
	Globulin	.90	Northern bur oak, 1936	do	8.02
	Glutelin	9.02	White oak, 1936	do	8.44
			Northern red oak, 1936	do	5.56

Attempts to precipitate albumin or globulin fractions from the peptizates of the acorn meals by the method described in paragraphs A and B failed. A 5 percent solution of the trichloracetic acid also failed to yield precipitates.

The alcohol-soluble proteins from the acorns precipitated very slowly by the method described in paragraph C above. The yield of protein was very low. Five hundred grams of northern red oak seed meal yielded 1.62 gm. of prolamin which contained 6.18 percent nitrogen. Acorns contain a large amount of alcohol-soluble gums that precipitate with the protein.

The water- and the salt-soluble extracts corresponding to the albumin and globulin fractions of the acorns were studied according to the procedure used by Hiller and Van Slyke (*4*), with tungstic acid as a precipitant. The peptizate from 20 gm. of seed meal was used in this study. The data obtained are given in table 4.

TABLE 4.—*Analysis of the albumin and globulin in acorns of three species of oak trees*

Tree species	Fraction	Total nitrogen in peptizate	Total nitrogen in filtrate	Nitrogen precipitated by tungstic acid	Amino nitrogen in peptizate
		Milligrams	*Milligrams*	*Milligrams*	*Milligrams*
White Oak	Albumin	85.29	83.47	1.82	24.63
	Globulin	9.84	1.46	8.38	
Northern bur oak	Albumin	93.54	88.75	4.79	21.42
	Globulin	9.56	4.98	4.58	
Northern red oak	Albumin	20.15	16.69	3.46	17.20
	Globulin	4.69	0	4.69	

ANALYSIS OF THE PROTEINS ISOLATED FROM THE TREE SEEDS

Moisture, ash, and total nitrogen were determined by the usual technique. The percentages of nitrogen were calculated on the moisture- and ash-free basis.

A nitrogen-distribution study was made according to the method of Van Slyke (*10*) as modified by Plimmer and Rosedale (*6*). *l*-Cystine determinations were made on the basic fraction and on the filtrate

from the bases by the method of Sullivan and Hess (*8*, *9*). Tyrosine and tryptophane were determined on a tenth of a gram of protein by the method developed by Folin and Ciocalteu (*2*) and modified by Folin and Marenzi (*3*) and Da Silva (*1*). The data from this experiment are given in table 5. All analyses were made in duplicate but only the averages are reported here.

TABLE 5.—*Nitrogen distribution of the proteins of various tree seeds in percentage of total nitrogen, calculated on a fat-, ash-, and moisture-free basis*

Distribution of nitrogen [1]	Ironwood			Elm			White oak	Northern bur oak	Northern red oak
	Albumin	Globulin	Glutelin	Albumin	Globulin	Glutelin	Glutelin	Glutelin	Glutelin
Acid-Insoluble humin nitrogen	1.33	0.67	3.35	2.15	1.18	2.40	3.16	4.34	3.19
Acid-soluble humin nitrogen	.67	.26	.32	.52	.34	.17	1.87	1.44	1.43
Phosphotungstic acid humin nitrogen	1.30	1.07	1.17	1.94	.98	.81	2.41	1.77	2.15
Amide nitrogen	10.67	10.69	11.25	7.84	10.63	8.67	10.86	9.78	11.80
Total nitrogen of the filtrate	51.35	52.75	49.66	50.95	47.71	51.04	51.87	54.54	54.37
Total nitrogen of the bases	34.81	35.29	34.48	36.49	39.29	36.61	29.94	28.46	27.01
Recovery	100.13	100.73	100.23	99.89	100.13	99.70	100.11	100.33	99.95
Amino nitrogen of the filtrate	45.36	46.72	44.98	34.50	41.00	44.88	47.10	49.76	35.71
Nonamino nitrogen of the filtrate	5.99	6.03	4.68	16.45	6.71	6.16	4.77	4.78	18.66
Amino nitrogen of the bases	13.24	13.26	12.08	16.28	14.80	14.94	13.04	12.52	11.37
Nonamino nitrogen of the bases	21.57	22.03	22.40	20.21	24.49	21.67	16.90	15.94	15.64
Arginine	27.97	27.38	27.14	22.81	29.61	28.63	19.20	16.65	18.24
Histidine	.89	2.25	3.07	4.65	3.28	5.52	3.75	5.19	2.96
Cystine:									
Bases	.14	.10	.12	.78	.58	.73	.39	.24	1.16
Filtrate	.40	.35	.32	1.05	.84	.88	.43	.43	1.24
Lysine	5.80	5.57	4.17	8.24	5.36	6.74	6.59	6.38	4.66
Tyrosine	1.11	1.21	1.12	1.82	.10	1.63	1.75	1.93	1.83
Tryptophane	.48	.82	1.44	.48	.53	1.52	1.69	1.94	1.25
Moisture	7.70	7.42	2.28	3.85	7.00	4.91	9.70	8.90	6.20
Ash	.6.20	1.86	1.10	5.72	.36	1.61	2.32	1.64	2.15
Nitrogen	16.94	18.54	12.61	15.53	19.19	14.80	13.04	12.83	10.74

[1] Determined by the method of Van Slyke (10) as modified by Plimmer and Rosedale (*6*).

DISCUSSION

PEPTIZATION

The peptization study on ironwood seed (table 1) suggests that there is a great difference in the nature of the protein laid down in the seed during a dry year (1933) and during a year when rainfall is normal (1937). The seed collected during the dry year of 1933 had a slightly higher total nitrogen content than the seed collected in 1937. This observation is in harmony with the findings of cereal chemists in studies of cereal grains, particularly wheat. The study further revealed that the crop of 1933 had a much larger water-soluble and salt soluble protein fraction, a correspondingly small alkali-soluble protein fraction, and less residual nitrogen than the crop of 1937. Since ironwood seed ripens in September climatic conditions in August and September must be considered in predicting the nigtrogen content of the seed.

The analyses of acorns from five varieties of oaks reveal that the seed of the red oak is much richer in fat than that of the white oak. The nitrogen content of all the different varieties of acorns is low

and the residual nitrogen accounts for from 18 to 40 percent of the total nitrogen. The major protein in acorns is a glutelin.

PROTEINS ISOLATED

Tungstic acid will precipitate proteins, peptones, and proteoses (*4*). An examination of table 4 with this in mind shows that there is very little protein nitrogen in the water-soluble (albumin) fraction from acorns and that a greater part of the nitrogen in the salt soluble fractions is protein in nature. Acorns are rich in alkali-soluble gums that precipitate with the protein, resulting in a product low in nitrogen.

VAN SLYKE ANALYSIS OF THE PROTEINS

An outstanding difference between the red oak and the two white oak proteins lies in the high nonamino nitrogen in the filtrate from the bases of the red oak. This includes the proline, oxyproline, and tryptophane nitrogen of the protein. The nitrogen distributions of the three protein fractions from ironwood seed are very much alike, while a similar comparison of the protein fractions of elm seed reveals a considerable difference.

The arginine content of the proteins examined is notably high and the arginine nitrogen represents the major percentage of the total basic nitrogen. These values range from 77.6 to 80.4 percent for the ironwood seeds, from 62.5 to 78.2 percent for the elm seeds, and from 58.5 to 67.5 percent for the acorns. Larmour (*5*) has collected the analyses of a variety of plant proteins; of these edestin is recognized as being rich in arginine with 81.6 percent of the basic nitrogen in this form, whereas the various cereal proteins contain 45 to 65 percent of the total basic nitrogen as arginine nitrogen. In this respect, as well as in the other constituents determined, the tree-seed proteins appear to be within the range reported for other edible-seed proteins.

SUMMARY AND CONCLUSIONS

The percentage of fat, ash, and total nitrogen in the following tree seeds has been determined: American elm, ironwood, white oak, northern bur oak, northern red oak, red oak, and northern pin oak.

The acorns from red oaks are richer in fat than the acorns from white oaks. Elm and ironwood seeds are rich in fat.

Acorns are low in protein, ironwood seeds are somewhat higher in protein, while elm seeds are very high in protein.

A peptization study on the proteins of the above-named tree seeds has been made. The water-soluble, saline-solution-soluble, alcohol-soluble, alkali-soluble, and residual nitrogen have been determined on the same sample of each seed meal.

The major proteins have been isolated from the seeds studied. From the American elm there were obtained an albumin, a globulin, and a glutelin. The same types of protein were isolated from ironwood seeds. From the three oaks only the glutelin fraction was obtained.

The above-named proteins have been analyzed for nitrogen distribution according to the method of Van Slyke (*10*).

Tyrosine, tryptophane, and cystine have been determined colori-

metrically. The last-named was determined on both the basic fraction and the filtrate from the bases.

The ratio of arginine nitrogen to total basic nitrogen is strikingly high, but in this respect is similar to that of other seed proteins.

The water- and salt-soluble nitrogen fractions from acorns of white oak, northern bur oak, and northern red oak have been studied with tungstic acid as a precipitant. The water-soluble fraction was chiefly nonprotein in nature while the saline-solution-soluble fraction was chiefly protein.

Acorns contain large amounts of alkali-soluble gums that interfere with the isolation of the major protein fractions. Eighteen to forty percent of the nitrogen is residual nitrogen.

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